Aquaponic Urbania:

Integrating High Tech Urban Agriculture with Sustainable Urban Design.

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Abstract:

In 2050 70 percent of the world's population is expected to be urban, and will see the birth of two new India (2.2 billion more people). These global challenges within a very short time period have given new attention towards Urban Agriculture and its potentials for contributing to the world's food supply. Aquaponic food systems (fish and vegetable production combined), holds the prospect of producing both healthy food and recycling organic waste in urban and peri-urban areas. A Scandinavian research project '*Aquaponic Urbania*', commencing in 2012 will establish a commercial and research innovative organic aquaponic production on top of a roof in the municipality of Copenhagen. Analysis will be targeting the prospects of utilizing city compost in the vegetable production and vermiculture as a protein supply for the fish in the aquaculture hence reducing the material flow in food chains concerning packaging and distributing food in the city.

Introduction:

Today 60 percent of the world's population is urban, and around the year 2050 the urban population is expected to have reached 70-75 percent. In the same period the world will also see the birth of 'two more India' (2.5 billion people) in terms of a population growth reaching a world population of 9.2 billion in 2050 (www.unpopulation.org World Population Prospects: The 2010 Revision). Most of this urban growth is expected to be absorbed by small and intermediate cities from less than ½ million to 1-5 million inhabitants. However, a growing proportion of the expected urban population will live in Mega-polis' or Mega-Urban-Regions (MUR), mostly in Asia, ranging from 10 million+ to 30 million habitants as we already know from them from Sao Paolo, Cairo, Mumbai and greater Shanghai MUR (83 million)(UN-Habitat, 2004/2005).

Most of the world's fastest growing cities are found in low-income countries of Asia and Africa with a large proportion of young people. Urbanization in low-income countries is in the same time accompanied by high levels of poverty, unemployment and food insecurity. Worldwide, an estimated one billion people live in crowded slums, without access to basic health, water and sanitation services. Approximately 30 percent of the developing world's urban population – 770 million people – are unemployed or "working poor", with incomes below the poverty lines (FAO, 2010).

As food demand grows, sprawl and unplanned urbanization exacerbate the degradation of forests, water sources and land in peri-urban areas. Poverty, unemployment, malnutrition and food insecurity are silent emergencies eroding the capacity to withstand disaster. The food price crisis in 2007-08 unveiled the inherent weakness in the world's food systems, which for the first time in human history affected the urban poor disproportionately, and made it a growing concern for many national and city authorities. This has enhanced the uptake of urban and peri-urban food production in city and national policies and programs directed towards strategies for food security and poverty reduction. In addition, the attention being paid to reducing the environmental footprint of cities (energy, CO", water and nutrients) and the potential impacts of climate change, as well as enhancing resilience, is growing (Zeeuw, Veenhuizen and Dubbeling, 2011).

Globally the UN Development Program estimates that 800 million people are involved in urban farming worldwide, with the majority in Asian cities. Of these, 200 million produce food primarily for the market, but the great majority raise food for their own families (Halweil and Nierenberg, 2007). In peri-urban areas, production is often intensive and commercially oriented, but farming within cities generally occurs on a smaller scale. It is commonly practiced on fallow public and private spaces, wetlands and underdeveloped areas; rarely is it found on lands specifically designated for agriculture. In many countries urban agriculture is informal and sometimes even illegal. Competition for land is a frequent source of conflict. Other contentious issues include the environmental impact of urban agriculture and food safety concerns, particularly relating to livestock production (FAO, August 2010).

To avoid or surpass some of the classical conflicts of interest within urban agriculture some urban farm producers have commenced to experiment with rooftop farming. The rooftop area can be regarded as a place of 'wasted' solar energy and opens up for producing fresh food right in the center of a metropolis. Likewise, utilizing 'empty rooftop space for food production makes it possible to reduce the material flow cycles and pollution by minimizing packaging and shortening transportation, as well as potentially recycle organic waste and nutrients. Rooftops planted with vegetables, bushes or other greens tend as well to cool the buildings in hot periods and isolate them in cold seasons.

However, this approach of 'vertical farming' carries new challenges that have to be weighed against the apparent opportunities. This goes in regards to the needs of a stronger and more expensive roof construction as well as questions on security in terms of being a workplace and risks of a greenhouse blowing off in a storm etc. If food production takes place on top of a building with residents, then questions on daily transports of farm inputs and outputs will have to be resolved. Are the residents and the urban food company going to use the same stairways/elevators or is it necessary to establish an open lift placed outside the building used by urban farmer as an example. Likewise, the questions on aesthetics of an urban roof top farm has to be taken into account if viewing the city as a landscape and the rooftop becomes part of such a landscape and scenery eyed upon from other nearby buildings.

In this paper the project of 'Aquaponic Urbania' will be presented and illustrate the potentials of an urban roof top farm targeting to solve a major part of the diverse challenges raised above. 'Aquaponic Urbania' is a commercial as well as a research oriented urban roof top farm project combining fish and vegetables into an organic aquaponic food production system and is to be situated in the capital of Copenhagen in Denmark.

What is Aquaponic Food systems?

Before the World new anything about the word aquaponics the Aztec Indians raised plants on rafts on the surface of Lake Tenochtitlan not far from present day Mexico City. They were formally a nomadic tribe which settled on the marshy shores of Lake Tenochtitlan leaving very little space for growing food. The Aztecs solved this constraint by constructing large rafts out of reeds and rushes which they found near the lake. They floated these rafts in the water and covered them with soil which they dredged up from the bottom of the shallow lake. On the rafts they planted vegetable crops on these floating islands also known as Chinampas (Aghajanian, 2007).

The famous Dike-Pond systems of China dating back to the 15 Century evolved out of a need to control regular floods in lower lying areas at the Pearl River Delta. The pond mud, much enriched in nutrients, served as fertilizer for crops. Ponds were drained two or three times a year, and the mud at the bottom was dredged up to put on the dykes, thereby raising and repairing the dikes and restoring the depth of the pond. Pond mud was also used for mushroom cultivation. Mushrooms were often cultivated on the floor of the silkworm shed in winter, the off-season for silkworm production. After the final crop of mushrooms had been harvested, the mud-bed was used to fertilize vegetables, fruit trees and grasses.

The pond was normally filled with river water. Water could also enter directly as rain and through runoffs from the dikes. Water left the pond via the pond drainage outlet in controlled discharges. It was also lost through evaporation and transpiration, via seepage into the dikes, and through being removed at regular intervals to water as well as fertilize the crops growing on the dikes.

Livestock is an important part in the Dike-pond production system. Pigs, chickens and ducks are reared on the dikes, to provide manure to fertilize the fishponds, and hence encourage the growth of plankton that feed the fish. Most dike crops are fed directly to the fish, such as elephant grass for the grass carp, or else to the livestock, such as forage crops for pigs.

In modern times aquaponics emerged from the aquaculture industry as fish farmers were exploring methods of raising fish while trying to decrease the dependence on land, water and resources. Aquaponic systems are defined as sustainable systems combining traditional aquaculture with hydroponics, where plants are cultivated in water – hence merging the two production systems and words into one: aquaponics. The aquaponic food system operates in such a way that the effluents from the aquaculture are utilized as nutrients for the plants in the hydroponics, thus creating a symbiotic natural environment with maximum utilization of all raw materials and waste (Nelson & Pade, 2008). The cleansed water from the plants are then recycled back to the fish tanks/ponds making A*quaponics one of the worlds' most productive food systems in terms of water efficiency*. The renewal of fresh water is only 1-2 percent of the total water volume in use.

Aquaponic systems vary in size from small units to large commercial units, using basically the same technology but can be organized within three different system designs:

- The raft
- The NFT (Nutrient Film Technique)
- The media-filled bed system

In a raft system the plants are grown in floating styrfoam boards that float on top of water. Most ofte, this is in a tank seperate from the fish tank (see photo 1).

NFT is a method in which the plants are grown in long narrow channels. A thin film of water continously flows down each channel, providing the plant roots with water, nutrients and oxygen.

A media-filled bed system uses a tank or container that is filled with gravel, perlite or another media for the plant bed. This bed is periodically flooded with water from the fish tank. The water then drains back to the fish tank.

Photo 1. Vegetables floating on rafts

Each of these three system designs have their own advantages as well as disadvantages, but in general the raft as a primary unit in combination with NFT channels have the most potential for commercial production because of stocking and planting densities are higher, resulting in larger output of fish and plants.

Figure 1 is illustrating a raft system design, with three points of important control and production units: The fish tanks, the filters with microroganisms for transforming organic matter into in-organic nutrients for the plants and thirdly the plant production itself. The systems can contain fresh water with production of herbs, vegetables or fruits, or salt water with so far focus on algae production. Even though the aquaponic science is still in its early stage some commercial units are available, e.g. in USA, China and Switzerland and a rapid development is now going on with Aquaponic companies rising in many countries, such as in Norway, UK, Denmark and Iceland.

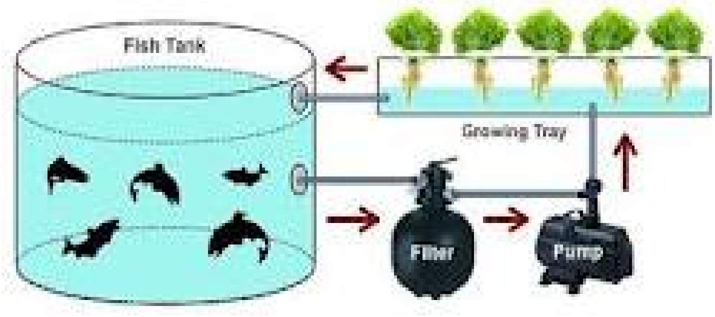

Figure 1: The principles of an Aquaponic food system

However, combining two hybrid systems into an aquaponic food system increases also the potential of problems. Besides the need for skill upgrading in handling and understanding the requirements of producing fish as well as plants there are also some compromises that need to be taken with the system so far. First of all there is a compromise in PH since most fish prefer a PH level at 7.5-8.0, whereas plants do best at a PH level at 6.0-6.5. The nitrifying bacteria in the filter tank do best at 7.0-8.0. The present optimal production in aquaponics is a PH level at 7.0. Secondly, water temperature is also an area of compromise and daily needed control. Tilapia fish will grow fastest at a temperature between 25.5-26.6C, whereas the bacteria will provide the best conversion from toxic to non-toxic elements at 25C. Most vegetables typically raised in aquaponics will grow best at 21.1C. The temperature range in compromise is between 22.2-23.3C.

Aquaponics is still in its infancy, but it has a huge potential to become a future farming method providing Year-round production of high quality fish, vegetables, fruits in a sustainable way at a low cost. The world needs more sustainable solutions, with more focus on resource management, minimizing waste and optimizing the use of water, energy, nutrients and other resources in food production.

Aquaponics is an innovative potential that can produce sustainable healthy food and proteins despite heavy constraints on water and productive soil. Likewise, it is a food system that holds the potential for controlling a stable food production despite climatic changes and expected weather extremes for the future.

The research areas of Aquaponic Urbania

The idea behind 'Aquaponic Urbania' is to establish an aquaponic production in the capital of Copenhagen in Denmark on top of a roof as a commercial business combined with innovative research. The placement on a roof opens up for utilizing wasted solar energy and supports the Municipality's goals of increasing the area of green roofs and becoming CO2 neutral in 2025 See photo 2).

The output from the commercial production is expected to consist of 1 tons of fish (Tilapia) and 50.000 green units (salads, herbs, strawberries, tomatoes, cucumbers) per year.

The greenhouse, containing 6 fish tanks and 2 rafts + NFT channels will be covering 400 M2 of the roof.

Photo 2: Aquaponic production placed on a roof

The research areas will focus at:

1) Minimizing the urban material flow in relation to supply food to the urban inhabitants

2) Increase productivity in the aquaponic food system
3) Prepare an economic production manual on aquaponics
4) Develop a blueprint on production rules for an organic aquaponic food system
5) Examine the economic potentials of using back flow heating in the building to warm up the green house

In more detail the research will examine:

Ad 1)

the cost and practicalities of utilizing city compost (organic food waste) in the vegetable production. In principle soil is not needed in an aquaponic production, but since the project 'Aquaponic Urbania' is to come up with a blueprint for rules in an organic aquaponic food system, soil is needed since soil is a requirement in organic greenhouse production.

From the city compost vermiculture shall be extracted and fed to the fish to analyze the economic trade-offs and potentials from substituting worms with maritime feed import. How much can the proteins in worms replace maritime feed imports and how much can the fish digest without quality changes in meat structure and consumer taste experience. And how much labor input would this extraction require weighed against the cost of maritime feed.

Likewise, analysis will examine savings and reduced CO_2 emissions by minimizing transport and packaging from producing food in the city.

Ad 2)

To increase productivity, analysis and testing of polyculture will take place in the fish tanks. Crayfish will be placed in cages at the bottom of the tank and share the tank with Tilapia swimming freely. The purpose is to examine how far the total biomass can be increased in a tank without causing health problems and diseases among the fish species in comparison with intensifying a monoculture of pure Tilapia.

Ad 3)

Make economic calculations and contribution margins on the various types of vegetables and herbs that can be produced in the greenhouse as well as the value from the fish produced. The purpose is to draw up 3 different types of production models within aquaponics: small, medium and large scale production.

Ad 4)

Presently the existing legislation does not permit organic aquaculture using closed recirculation animal production facilities and the feasibility of extending the rules to include such production systems in the future needs to be examined as a priority. Such systems could be permitted in the planned organic aquaculture section of the Codex Alimentarius Guidelines on organic production. The aim of the analysis is to strengthen the science base of the existing regulatory framework and support a possible future revision of this regulation (currently planned for 2013).

Ad 5)

The use of the back flow heating from the building to heat the greenhouse will be analyzed and compared with the energy costs needed to heat a greenhouse standing free range in a rural setting. The costs of heating the greenhouse on the roof will be compared with the potentials of the greenhouse isolating the building in winter periods.

Conclusive remarks

Aquaponic Urbania is to be established on a roof top in Copenhagen municipality in 2012. Full production is expected to run during 2013, and then the research tasks will commence. The aim is push the economic threshold for market oriented urban agriculture so it becomes commercially viable in urban centers, and not only at the city fringe. By establishing the production on a rooftop the purpose is to avoid the many conflicts of interest that normally follow urban agriculture when placed on the ground. However, the extra costs have to be weighed against benefits, but also open up for smart thinking when integrating urban food production in future urban designs and city planning. Aquaponic food systems hold in this regard the prospects of producing both fish and vegetables right in the heart of a city, utilize organic city waste and contribute in closing the material flow cycle. As a sustainable food system technique aquaponics will inevitably be growing parallel with the expansion of urban agriculture and contribute with the needed food supplies for an urban world.

Literature:

Aghjanian, Alfred (2007) *Chinampas: Their role in Aztec empire – building and expansion,* Indo-European Publishing.Com, LA, CA, USA

FAO (2010) *Growing greener cities*, www.fao.org

Rebecca L. Nelson and John S. Pade (2008): *Aquaponic Food Production – Raising fish and plants for food and profits*, Nelson & Pade Inc.

FAO (August 2010) *Fighting Poverty and Hunger – What role for urban Agriculture?* Policy Brief 10, Economic and social perspectives, August 2010

Halweil, Brian and Danielle Nierenberg (2007) *Farming the Cities,* chapter 3 in: State of the world – our urban future, pp. 48-65

UN-Habitat (2004-05) *The State of the World's Cities 2004/05 – Globalization and the Urban Culture,* Earthscan London

Zeeuw, H. De, R. van Veenhuizen and M. Dubbeling (2011): *The role of urban agriculture in building resilient cities in developing countries*, Journal of Agricultural Science, pp. 1-11, Cambridge University Press 2011